Energy, Mines and Resources Canada | Énergie, Mines et Ressources Canada

CANMET

Canada Centre for Mineral and Energy Technology | Centre canadien de la technologie des minéraux et de l'énergie

EXAMINATION OF URL-1, URL-2 and URL-5 UNIAXIAL COMPRESSIVE AND TENSILE TEST DATA

M. Bétournay
Rock Mechanics Laboratory

March 1983

This document is an unedited [illegible] report prepared [illegible] for discussion and information [illegible] reporting purposes. It represents a final [illegible] the opinion of the [illegible] for Mineral and Energy Technology (CANMET).

Ce document est un rapport [illegible] préparé et rédigé [illegible] fin de [illegible] de communication [illegible] basée sur [illegible] ou définitive de [illegible] Centre canadien de [illegible] des minéraux et de l'énergie (CANMET).

33pp

ENERGY RESEARCH PROGRAM
MINING RESEARCH LABORATORIES
DIVISION REPORT ERP/MRL 83-26(TR)

MICROMEDIA
DEC 22 198[illegible]

CONTENTS

	Page
INTRODUCTION (E)	1
INTRODUCTION (F)	1a
ANALYSIS DESCRIPTION	2
Petrological Characteristics	2
Zones of Fracturing	2
Elastic Modulus	2
DISCUSSION	2
Uniaxial Compressive Strength	2
Tensile Strength	3
CONCLUSIONS	4
REFERENCES	5

TABLES

No.		
1(a).	Summary of uniaxial strength, elastic and dilatational velocity for URL engineering standard specimens (URL-2)	6
1(b).	Summary of uniaxial strength, elastic and dilatational velocity for URL engineering standard specimens (URL-1 & 5) ..	8
2.	Brazilian tensile strength test results: extended engineering specimens from boreholes URL-1 and URL-5	9
3(a).	Type one classification: compressive strength characteristics according to petrological grouping - grey granite	10
3(b).	Type one classification: compressive strength characteristics according to petrological grouping - pink granite	11
3(c).	Type one classification: compressive strength characteristics according to petrological grouping - combined rock types	11
3(d).	Type one classification: compressive strength characteristics according to petrological grouping - comparison of upper level pink and grey granite	12
4.	Type one classification: tensile strength characteristics combined data	13
5(a).	Type two classification - legend (URL1, 2, 5 borehole fracturing delineation)	14

CONTENTS (cont'd)

No.		Page
5(b).	Type two classification: compressive strength characteristics, upper massive zone (zone 1)	15
5(c).	Type two classification: compressive strength characteristics, upper fracture zone (zone 2)	15
5(d).	Type two classification: compressive strength characteristics, middle massive zone (zone 3)	16
5(e).	Type two classification: compressive strength characteristics, lower fracture zone (zone 4)	17
5(f).	Type two classification: compressive strength characteristics, lower massive zone (zone 5)	18
6(a).	Type two classification: tensile strength characteristics, upper massive zone (zone 1)	19
6(b).	Type two classification: tensile strength characteristics, upper massive fracture zone (zone 2)	19
6(c).	Type two classification: tensile strength characteristics, middle massive zone (zone 3)	20
6(d).	Type two classification: tensile strength characteristics, lower massive fracture zone (zone 4)	20
6(e).	Type one classification: tensile strength properties, lower massive zone (zone 5)	21
7(a).	Type three classification: compressive strength characteristics, upper portion elastic modulus	22
7(b).	Type three classification: compressive strength characteristics, middle portion elastic modulus	23
7(c).	Type three classification: compressive strength characteristics, lower portion elastic modulus	24
8.	Type three characteristics: tensile strength characteristics, elastic modulus grouping of all specimens tested	25

CONTENTS (cont'd)

FIGURES

No.		Page
1.	Plan, URL boreholes location	26
2.	Section A-A, projection of borehole data on vertical plane oriented N60E	27
3.	Section A-A, delineation of borehole horizons based on elastic modulus	28

EXAMINATION OF URL-1, URL-2 and URL-5 UNIAXIAL COMPRESSIVE AND TENSILE TEST DATA

by

M. Bétournay*

INTRODUCTION

The following analysis reviews the uniaxial compression and Brazilian test data (1,2) on specimens from boreholes URL-1, URL-2 and URL-5 to bear out trends or significant distributions. The cylindrical test specimens, obtained from a wide range of borehole elevations, measured on average 96.4 mm axially, 44.9 mm diametrically for compressive testing and 23.14 mm axially, 44.8 mm diametrically for tensile testing. The rock type tested is a consistently massive granite, grey medium to coarse grained, altered to varying levels of pink coloration; most of the grey samples also exhibit a marked green alteration, usually 15-25% of the specimens.

Data comparisons are based on laboratory testing and core log data; petrological data on each of the tested specimens was not available at the time of writing this report for correlation with uniaxial or Brazilian tests.

The following classifications were used for data analysis:

1) Petrological characteristics
2) Zones of fracturing
3) Elastic modulus.

Comparisons based on ground stress are not possible because of the absence of sufficient measurements. Mean and standard deviation are used to appraise the significance of the results. Uniaxial compression and Brazilian tensile test data used in this report are summarized in Table 1 and 2, respectively.

---

*Physical Scientist, Rock Mechanics Laboratory, Mining Research Laboratories, CANMET, Energy, Mines and Resources Canada.

ÉTUDE DES DONNÉES DES ESSAIS DE COMPRESSION UNIAXIALE ET DE TRACTION

par

M. Bétournay*

INTRODUCTION

L'analyse suivante passe en revue les données des essais de compression uniaxiale et brésiliens (1,2) recueillies aux trous de forage URL-1, URL-2 et URL-5 pour identifier les tendances communes et les distributions importantes. Les échantillons d'essais cylindriques, obtenus à partir d'une large variété d'élévation de trous de forage, mesuraient environ 96,4 mm de ligne axiale, 44,9 mm diamétralement pour les tests de compression, et 23,14 mm de ligne axiale et 44,8 mm diamétralement pour les essais de traction. Le type de roche dont on a fait l'essai est un granit en amas, de grains moyens à gros, de couleur gris avec différents tons de rose. De 15% à 25% des échantillons gris portaient des altérations vertes très marquées.

La comparaisons des données a été faite selon des essais en laboratoire et des données sur les carottes. A la rédaction de ce rapport aucun des échantillons n'a été étudié pétrographiquement ou autrement dans le but d'établir une corrélation avec les essais uniaxiaux ou brésiliens.

On a utilisé les classifications suivantes lors de l'analyse des données:

1) caractéristique pétrographiques
2) zones de fracture
3) module d'élasticité.

Les comparaisons fondées sur les pressions de terrains ont été impossibles à obtenir à cause de l'absence de mesures suffisantes. La moyenne et la déviation aux normes ont été utilisées pour évaluer l'importance des résultats. Les données des essais de compression uniaxiale et des essais de traction brésiliens utilisés dans ce rapport sont résumées aux tableaux 1 et 2 respectivement.

*Chercheur scientifique, Laboratoire de la mécanique des roches, Laboratoires de recherche minière, CANMET, Énergie, Mines et Ressources Canada.

ANALYSIS DESCRIPTION

PETROLOGICAL CHARACTERISTICS

Rock type is used here as a comparative base against compressive and tensile strength, elastic modulus and Poisson's ratio, Table 3, 4. Except for a direct relationship between fracturing and level of pink alteration, there is no other accordance of depth with rock type. Few of the samples tested originated from fracture zones (Fig. 2). Only grey granite was used for tensile tests.

ZONES OF FRACTURING

The presence of two fracture zones outlines horizons within the rock mass that can be examined comparatively. The similar horizons between boreholes are grouped for examination, Table 5 and 6. Table 5(a) and Fig. 2 outline the similarity of each horizon between the boreholes.

ELASTIC MODULUS

There exists a definite grouping of values for the elastic modulus of tested specimens, against which depth, uniaxial strength and tensile strength can be compared; the groups are: ~70-80 GPa located in the upper portion, ~60-66 GPa located in the centre portion and ~51-59 GPa located in the lower portion, Table 7 and Fig. 3.

DISCUSSION

UNIAXIAL COMPRESSIVE STRENGTH

All three classifications can be used to represent the features of the URL host rock, but examination of their results indicates important differences.

Although homogeneous in original geologic formation the rock mass does not seem to warrant similar consideration as for strength and deformation properties. Statistically grey granite (samples with much green alteration) is weaker than pink, Table 3(b); it must be noted here however, that all of the latter type originated from the upper reaches of the rock mass, which, as borne out later, exhibits higher strength characteristics than the lower reaches. Table 3(c), comparing upper pink and upper grey reaffirms the domi-

nance of the pink variety (note: no degree of alteration was given to the sample classification, they were either "pink" or "grey"). These results must also be examined in the light of the direct relationship between the level of alteration and fracturing in the rock mass.

With respect to the compressive strength, grey granite averaged 179 ± 18.9 MPa while the pink was 209 ± 19.9 MPa. The overall average for all URL specimens is 186 ± 21.9 MPa. The modulus of elasticity and Poisson's ratio reflect the same order of values: 62.6 ± 7.8 GPa, 0.25 ± 0.5 for the grey, 71.0 ± 5.4 GPa, 0.27 ± 0.07 for the pink and 64.9 ± 8.1 GPa, 0.26 ± 0.05 for the combined data. The high value of the standard deviation associated with these results precludes any serious distributions.

The other two classifications relate more to existing ground conditions. Type two classificaton indicates that compressive strength, elastic modulus and poisson's ration decrease with depth, i.e., with each successive unfractured horizon. The upper zone averages 224 ± 5.0 MPa, 72.4 ± 0.5 GPa and 0.24 ± 0.02 for compressive strength, elastic modulus and poisson's ratio, respectively, the middle 188 ± 15.6 MPa, 70.5 ± 3.9 GPa and 0.26 ± 0.05 and the lower 172 ± 18.0 MPa, 57.0 ± 4.3 GPa and 0.25 ± 0.05. The persistently lower standard deviation at all levels supports this trend.

The third classification, based on experimental results, refines the previous classification; the results, with significantly low standard deviations, reaffirm the deeper-weaker relation. The spread of sample provenance is enough that the elastic modulus groupings fall in three distinct portions in the rock mass with clear cut boundaries at approximately the same elevation for each borehole, Fig. 3. The first portion is present from el. 280 - 25 m the second from el 25 - 5 m and the third below el. 5 m. The upper portion features 196 ± 16.9 MPa, 71.8 ± 2.7 GPa and 0.26 ± 0.05, the middle one 187 ± 15.7 MPa, 64.8 ± 1.8 GPa and 0.25 ± 0.02, the lower one 166 ± 16.0 MPa, 55.2 ± 2.4 GPa 0.25 ± 0.06, for compressive strength, elastic modulus and Poisson's ratio, respectively.

TENSILE STRENGTH

The specimens tested, all grey granite, averaged 8.7 ± 1.0 MPa; the results bear out the same trends as the uniaxial compressive strength: diminishing tensile strength with depth. Type two classification displays a middle zone of 9.1 ± 0.7 MPa, a lower zone of 7.6 ± 1.5 MPa. Type three classification (using the same elastic modulus breakdown as for compressive strength) has an upper portion of 9.3 ± 0.5 MPa and a middle one of 7.9 ± 0.9 MPa.

CONCLUSIONS

The URL-1, URL-2 and URL-5 cores are composed of grey granite altered to various levels of pink or green alteration. Examination of petrological observations before testing might establish relationships between level of alteration and strength properties. The alteration follows one pattern: the level of alteration in the rock mass increases with the number of fractures. Two major fracture zones can be detected from most drillholes. Since one sample from the fracture zones was tested, it is difficult to associate strength with degree of fracturing (and therefore pink alteration and pink granite strength). The situation here is most likely one of fracturing than alteration; the good relationship between number of fractures and degree of alteration would indicate this. When enough samples of pink granite are tested from all zones, not only will the strength of pink granite within fracture zones be established, but also its properties compared to grey granite, as in the case of the upper massive zone, where it is stronger than the grey variety.

The specimens, when grouped as in actual unfractured zones, or as similar modulus of elasticity values, follow significant statistical trends. The latter to such a degree that three definite portions exist within the entire rock mass exhibiting narrowly defined strength features: decreasing strength (uniaxial compressive and tensile), Poisson's ratio and modulus of elasticity from one portion to the lower one.

REFERENCES

1. Jackson, R. "Dilatational velocity, Young's modulus, Poisson's ratio and uniaxial compressive strength for URL-2 and URL-5 samples"; CANMET Division Report ERP/MRL 82-60(TR); 1982.

2. Jackson, R. "Dilatational velocity, Young's modulus, Poisson's ratio, uniaxial compressive strength and Brazilian tensile strength for URL-1 and URL-5 extended engineering samples"; CANMET Division Report ERP/MRL 82-61(TR); 1982.

Table 1(a) - Summary of uniaxial strength, elastic and dilatational velocity for URL engineering standard specimens (URL-2)

Specimen identification	Length (mm)	Diameter (mm)	Density (g/cm^3)	Compressive strength (MPa)	Elastic modulus (GPa)	Poisson's ratio	Dilatational velocity (km/sec)	Dynamic modulus (GPa)	Rock type
URL-2-256.0	97.5	45.0	2.63	203	64.9	0.25	3.84	48.2	grey granite
URL-2-448.1	96.7	44.9	2.64	179	53.5	0.22	3.70	50.1	grey granite
URL-2-586.0	97.3	44.9	2.62	181	53.6	0.26	3.16	44.6	grey granite
URL-2-705.7	94.2	44.9	2.63	152	56.2	0.23	3.49	58.6	grey granite
URL-2-798.6	97.3	45.1	2.64	158	58.5	0.13	3.66	60.3	grey granite
URL-2-871.5	97.3	44.9	2.63	163	53.8	0.29	3.43	40.7	grey granite
URL-2-1001.2	97.0	45.0	2.63	156	51.0	0.25	2.82	38.5	grey granite
URL-2-1094.8	98.2	45.0	2.63	172	55.9	0.30	2.91	35.3	grey granite

[After Jackson, 1982 (1)]

Table 1(a) - Summary of uniaxial strength, elastic and dilatational velocity for URL engineering standard specimens (URL-5)

Specimen identification	Length (mm)	Diameter (mm)	Density (g/cm^3)	Compressive strength (MPa)	Elastic modulus (GPa)	Poisson's ratio	Dilatational velocity (km/sec)	Dynamic modulus (GPa)	Rock type
URL-5-16.4	98.6	44.9	2.62	219	73.0	0.27	5.07	65.7	pink granite
URL-5-76.9	97.1	45.0	2.65	230	71.9	0.22	5.67	87.6	pink granite
URL-5-108.3	96.8	44.9	2.59	199	72.5	0.38	5.14	45.8	pink granite
URL-5-126.6	95.6	45.0	2.64	175	70.4	0.18	5.05	73.9	pink granite
URL-5-157.2	96.2	44.8	2.59	180	71.4	0.26	4.97	61.6	pink granite
URL-5-199.1	98.1	44.8	2.63	191	73.5	0.31	5.09	59.6	pink granite
URL-5-246.5	97.6	44.9	2.63	226	69.0	0.25	5.45	70.7	pink granite
URL-5-289.7	94.9	45.0	2.63	197	66.2	0.24	4.07	53.0	grey granite
URL-5-334.0	96.9	44.6	2.68	130	58.8	0.25	4.40	55.9	grey granite
URL-5-370.0	97.4	45.1	2.63	176	56.2	0.25	3.77	47.7	grey granite
URL-5-450.9	97.0	45.2	2.65	163	54.1	0.37	3.48	29.2	grey granite
URL-5-496.8	97.1	44.7	2.65	186	53.1	0.27	3.52	41.0	grey granite

[After Jackson, 1982 (1)]

Table 1(b) - Summary of uniaxial strength, elastic and dilatational velocity for URL engineering standard specimens (URL-1 & 5)

Specimen identification	Length (mm)	Diameter (mm)	Density (g/cm^3)	Compressive strength (MPa)	Elastic modulus (GPa)	Poisson's ratio	Dilatational velocity (km/sec)	Dynamic modulus (GPa)	Rock type
URL-1-177.40	97.0	44.3	2.63	184	69.7	0.25	4.90	63.1	grey granite
URL-1-184.68	95.9	44.8	2.62	192	70.9	0.27	5.06	60.9	grey granite
URL-1-191.38	95.7	44.8	2.62	176	71.4	0.25	5.17	69.2	grey granite
URL-1-282.68	94.4	44.8	2.63	203	70.9	0.19	4.57	61.9	grey granite
URL-1-292.90	92.8	44.6	2.65	160	65.8	0.22	4.85	63.4	grey granite
URL-1-299.90	96.7	44.9	2.62	177	65.8	0.24	4.51	56.0	grey granite
URL-5-128.99	97.3	45.0	2.63	196	71.4	0.29	4.87	55.4	pink granite
URL-5-133.00	96.8	45.0	2.64	221	80.0	0.30	5.00	59.1	pink granite
URL-5-138.63	97.0	44.8	2.62	189	69.9	0.32	4.79	51.6	pink granite
URL-5-274.51	95.6	45.1	2.64	180	58.1	0.22	4.03	51.7	grey granite
URL-5-277.57	96.9	45.0	2.62	193	64.9	0.26	3.95	48.0	grey granite
URL-5-281.63	96.1	45.0	2.62	191	61.4	0.28	4.08	50.6	grey granite

[After Jackson, 1982 (2)]

Table 2 - Brazilian tensile strength test results: Extended engineering specimens from boreholes URL-1 and URL-5

Specimen No.	Thickness (mm)	Diameter (mm)	Density (gm/cc)	Tensile strength (MPa)
URL-1 177.50	22.21	44.80	2.62	9.3
URL-1 184.34	23.76	44.72	2.63	9.6
URL-1 184.37	21.87	44.72	2.62	9.6
URL-1 191.67	23.69	44.75	2.62	9.5
URL-1 283.07	23.51	44.80	2.62	9.0
URL-1 292.87	23.25	44.53	2.64	8.6
URL-1 293.00	22.80	44.50	2.66	8.1
URL-1 300.00	23.70	44.80	2.62	8.2
URL-5 127.87	22.20	44.97	2.61	8.8
URL-5 133.12	23.42	44.98	2.63	9.8
URL-5 133.25	23.67	45.00	2.63	8.2
URL-5 138.98	23.18	44.72	2.61	9.9
URL-5 274.61	23.40	45.14	2.63	8.0
URL-5 274.64	23.94	45.13	2.63	9.0
URL-5 277.78	23.40	44.49	2.61	7.2
URL-5 281.73	22.24	44.86	2.63	6.2

[After Jackson, 1982 (2)]

Table 3(a) - Type one classification: compressive strength characteristics according to petrological grouping - grey granite

Rock type	Specimen	Uniaxial compressive strength (MPa)	Elastic modulus (GPa)	Poisson's ratio
Grey granite	URL-1-177.4	184	69.7	0.25
	URL-1-184.68	192	70.9	0.27
	URL-1-191.38	176	71.4	0.25
	URL-1-282.68	203	70.9	0.19
	URL-1-292.9	160	65.8	0.22
	URL-1-299.9	177	65.8	0.24
	URL-2-256.0	203	64.9	0.25
	URL-2-448.1	179	53.5	0.22
	URL-2-586.0	181	53.6	0.26
	URL-2-705.7	152	56.2	0.23
	URL-2-798.6	158	58.5	0.13
	URL-2-871.5	163	53.8	0.29
	URL-2-1001.2	156	51.0	0.25
	URL-2-1094.8	172	55.9	0.30
	URL-5-126.6	175	70.4	0.18
	URL-5-128.99	196	71.4	0.29
	URL-5-133.0	221	80.0	0.30
	URL-5-138.63	189	69.9	0.32
	URL-5-274.51	180	58.1	0.22
	URL-5-277.57	193	64.9	0.26
	URL-5-281.63	191	61.4	0.28
	URL-5-289.7	197	66.2	0.24
	URL-5-334.0	130	58.8	0.25
	URL-5-370.0	176	56.2	0.25
	URL-5-450.9	163	54.1	0.37
	URL-5-496.8	186	53.1	0.27
	n = 26	$\bar{x}$ = 179	$\bar{y}$ = 62.6	$\bar{z}$ = 0.25
		S_x = 18.9	S_y = 7.3	S_z = 0.05

Table 3(b) - Type one classification: compressive strength characteristics according to petrological grouping - pink granite

Rock type	Specimen	Uniaxial compressive strength (MPa)	Elastic modulus (GPa)	Poisson's ratio
Pink granite	URL-5- 16.4	219	73.0	0.27
	URL-5- 76.9	230	71.9	0.22
	URL-5-108.3	199	72.5	0.38
	URL-5-126.6	175	70.4	0.18
	URL-5-128.99	196	71.4	0.29
	URL-5-135.00	221	80.0	0.30
	URL-5-138.63	189	69.9	0.32
	URL-5-157.2	180	58.1	0.22
	URL-5-199.1	191	73.5	0.31
	URL-5-246.5	226	69.0	0.25
	n = 10	$\bar{x}$ = 203	$\bar{y}$ = 71.0	$\bar{z}$ = 0.27
		S_x = 19.9	S_y = 5.4	S_z = 0.07

Table 3(c) - Type one classification: compressive strength characteristics according to petrological grouping - combined rock types

Rock type	Specimen	Uniaxial compressive strength (MPa)	Elastic modulus (GPa)	Poisson's ratio
	n = 36	$\bar{x}$ = 186	$\bar{y}$ = 64.9	$\bar{z}$ = 0.26
		S_x = 21.9	S_y = 8.1	S_z = 0.05

Table 3(d) - Type one classification: compressive strength characteristics according to petrological grouping - comparison of upper level pink and grey granite

Rock type	Specimen	Uniaxial compressive strength (MPa)	Elastic modulus (GPa)	Poisson's ratio
Grey granite	URL-1-177.4	184	69.7	0.25
	URL-1-184.68	192	70.9	0.27
	URL-1-191.38	176	71.4	0.25
	URL-1-282.68	203	70.9	0.19
	n = 4	$\bar{x}$ = 189	$\bar{y}$ = 70.7	$\bar{z}$ = 0.24
		S_x = 11.5	S_y = 0.7	S_z = 0.03
Pink granite	URL-5- 16.4	219	73.0	0.27
	URL-5- 76.9	230	71.9	0.22
	URL-5-108.3	199	72.5	0.38
	URL-5-126.6	175	70.4	0.18
	URL-5-128.99	196	71.4	0.29
	URL-5-133.00	221	80.0	0.30
	URL-5-138.63	189	69.9	0.32
	URL-5-157.2	180	71.4	0.26
	URL-5-199.1	191	73.5	0.31
	URL-5-246.5	226	69.0	0.25
	n = 10	$\bar{x}$ = 200	$\bar{y}$ = 72.2	$\bar{z}$ = 0.28
		S_x = 18	S_y = 2.6	S_z = 0.06

Table 4 - Type one classification: tensile strength characteristics combined data

Rock type	specimen	Tensile strength (MPa)
Grey granite	URL-1-177.50	9.3
	URL-1-184.34	9.6
	URL-1-184.37	9.6
	URL-1-191.67	9.5
	URL-1-283.07	9.0
	URL-1-292.87	8.6
	URL-1-293.00	8.1
	URL-1-300.00	8.2
	URL-5-127.87	8.8
	URL-5-133.12	9.8
	URL-5-133.25	8.2
	URL-5-138.98	9.9
	URL-5-274.61	8.0
	URL-5-274.64	9.0
	URL-5-277.78	7.2
	URL-5-281.73	6.2
	n = 16	$\bar{x}$ = 8.7
		S_x = 1.0

Table 5(a) - Type two classification - legend

URL1, 2, 5 borehole fracturing delineation

	Borehole depth	Rock quality	Zone designation
URL-1	0-67 m		
URL-2	0-40 m	little or no fracturing	1
URL-5	0-80 m		
URL-1	67-152 m		
URL-2	40-175 m	moderate to strong fracturing	2
URL-5	80-112 m		
URL-1	152-320 m		
URL-2	175-~350 m	little or no fracturing	3
URL-5	112-206 m		
URL-1	320-335 m		
URL-2	not present	moderate to strong fracturing	4
URL-5	206-265 m		
URL-1	335-end		
URL-2	~350-end	little or no fracturing	5
URl-5	265-end		

Table 5(b) - Type two classification: compressive strength characteristics, upper massive zone (zone 1)

Rock type	Specimen	Uniaxial compressive strength (MPa)	Elastic modulus (GPa)	Poisson's ratio
Pink granite	URL-5-16.4	219	73.0	0.27
	URL-5-76.9	230	71.9	0.22
	n = 2	$\bar{x}$ = 224	$\bar{y}$ = 72.4	$\bar{z}$ = 0.24
		S_x = 5	S_y = 0.5	S_z = 0.02

Table 5(c) - Type two classification: compressive strength characteristics, upper fracture zone (zone 2)

Rock type	Specimen	Uniaxial compressive strength (MPa)	Elastic modulus (GPa)	Poisson's ratio
Pink granite	URL-5-108.3	199	72.5	0.38

Table 5(d) - Type two classification: compressive strength characteristics, middle massive zone (zone 3)

Rock type	Specimen	Uniaxial compressive strength (MPa)	Elastic modulus (GPa)	Poisson's ratio
Grey granite	URL-1-177.40	184	69.7	0.25
	URL-1-184.68	192	70.9	0.27
	URL-1-191.38	176	71.4	0.25
	URL-1-282.68	203	70.9	0.19
	URL-1-292.90	160	65.8	0.22
	URL-1-299.90	177	65.8	0.24
Grey granite	URL-2-256.0	203	64.9	0.25
Pink granite	URL-5-126.6	175	70.4	0.18
	URL-5-128.99	196	71.4	0.29
	URL-5-133.00	221	80.0	0.30
	URL-5-138.63	189	69.9	0.32
	URL-5-157.20	180	71.4	0.26
	URL-5-199.10	191	73.5	0.31
	n = 13	$\bar{x}$ = 188	$\bar{y}$ = 70.5	$\bar{z}$ = 0.26
		S_x = 15.6	S_y = 3.9	S_z = 0.04

Table 5(e) - Type two classification: compressive strength characteristics, lower fracture zone (zone 4)

Rock type	Specimen	Uniaxial compressive strength (MPa)	Elastic modulus (GPa)	Poisson's ratio
NO SPECIMENS TESTED FROM THIS ZONE				

Table 5(f) - Type two classification: compressive strength characteristics lower massive zone (zone 5)

Rock type	Specimen	Uniaxial compressive strength (MPa)	Elastic modulus (GPa)	Poisson's ratio
Grey granite	URL-2-448.1	179	53.5	0.22
	URL-2-586.0	181	53.6	0.26
	URL-2-705.7	152	56.2	0.23
	URL-2-798.6	158	58.5	0.13
	URL-2-871.5	163	53.8	0.29
	URL-2-1001.2	156	51.0	0.25
	URL-2-1094.8	172	55.9	0.30
Grey granite	URL-5-274.51	180	58.1	0.22
	URL-5-277.57	193	64.9	0.26
	URL-5-281.63	191	61.4	0.28
	URL-5-289.7	197	66.2	0.24
	URL-5-334.0	130	58.8	0.25
	URL-5-370.0	176	56.2	0.25
	URL-5-450.9	163	54.1	0.37
	URL-5-496.8	186	53.1	0.27
	n = 15	$\bar{x}$ = 172	$\bar{y}$ = 57.0	$\bar{z}$ = 0.25
		S_x = 18	S_y = 4.3	S_z = 0.05

Table 6(a) - Type two classification: tensile strength characteristics, upper massive zone (zone 1)

Rock type	specimen	Tensile strength (MPa)
NO SPECIMENS TESTED FROM THIS ZONE		

Table 6(b) - Type two classification: tensile strength characteristics, upper massive fracture zone (zone 2)

Rock type	specimen	Tensile strength (MPa)
NO SPECIMENS TESTED FROM THIS ZONE		

Table 6(c) - Type two classification: tensile strength characteristics, middle massive zone (zone 3)

Rock type	specimen	Tensile strength (MPa)
Grey granite	URL-1-177.50	9.3
	URL-1-184.34	9.6
	URL-1-184.37	9.6
	URL-1-191.67	9.5
	URL-1-283.07	9.0
	URL-1-293.00	8.6
	URL-1-293.00	8.1
	URL-1-300.00	8.2
	URL-5-127.87	8.8
	URL-5-133.12	9.8
	URL-5-133.25	8.2
	URL-5-138.98	9.9
	n = 12	$\bar{x}$ = 9.1
		S_x = 0.7

Table 6(d) - Type two classification: tensile strength properties, lower massive fracture zone (zone 4)

Rock type	specimen	Tensile strength (MPa)

NO SPECIMENS TESTED FROM THIS ZONE

Table 6(e) - Type one classification: tensile strength properties, lower massive zone (zone 5)

Rock type	specimen	Tensile strength (MPa)
Grey granite	URL-5-274.61	8.0
	URL-5-274.64	9.0
	URL-5-277.78	7.2
	URL-5-281.73	6.2
	n = 4	$\bar{x}$ = 7.6
		S_x = 1.5

Table 7(a) - Type three classification: compressive strength characteristics, upper portion elastic modulus

Rock type	Specimen	Uniaxial compressive strength (MPa)	Elastic modulus (GPa)	Poisson's ratio	Real depth (m)
Grey granite	URL-1-177.4	184	69.7	0.25	171.00
	URL-1-184.68	192	70.9	0.27	177.90
	URL-1-191.38	176	71.4	0.25	184.40
	URL-1-282.68	203	70.9	0.19	271.78
Pink granite	URL-5- 16.4	219	71.9	0.22	16.15
	URL-5-108.3	199	72.5	0.38	104.58
	URL-5-126.6	175	70.4	0.18	122.58
	URL-5-128.99	196	71.4	0.29	124.93
	URL-5-133.00	221	80.0	0.30	128.88
	URL-5-138.63	189	69.9	0.32	134.41
	URL-5-157.2	180	71.4	0.26	152.35
	URL-5-199.1	191	73.5	0.31	192.85
	URL-5-246.5	226	69.0	0.25	238.40
	n = 13	$\bar{x}$ = 196	$\bar{y}$ = 71.8	$\bar{z}$ = 0.26	
		S_x = 16.9	S_y = 2.7	S_z = 0.05	

Table 7(b) - Type three classification: compressive strength characteristics, middle portion elastic modulus

Rock type	Specimen	Uniaxial compressive strength (MPa)	Elastic modulus (GPa)	Poisson's ratio	Real depth (m)
Grey granite	URL-1-292.9	160	65.8	0.22	281.33
	URL-1-299.9	177	65.8	0.24	287.87
Grey granite	URL-2-256.0	203	64.9	0.25	247.13
Grey granite	URL-5-277.57	193	64.9	0.26	268.66
	URL-5-281.63	191	61.4	0.28	272.39
	URL-5-289.7	197	66.2	0.24	279.43
	n = 6	$\bar{x}$ = 187	$\bar{y}$ = 64.8	$\bar{z}$ = 0.25	
		S_x = 15.7	S_y = 1.8	S_z = 0.02	

Table 7(c) - Type three classification: compressive strength characteristics, lower portion elastic modulus

Rock type	Specimen	Uniaxial compressive strength (MPa)	Elastic modulus (GPa)	Poisson's ratio	Real depth (m)
Grey granite	URL-2-448.1	179	53.5	0.22	430.08
	URL-2-586.0	181	53.6	0.26	559.39
	URL-2-705.7	152	56.2	0.23	668.50
	URL-2-798.6	158	58.5	0.13	751.70
	URL-2-871.5	163	53.8	0.29	815.33
	URL-2-1001.2	156	51.0	0.25	925.58
	URL-2-1094.5	172	55.9	0.30	1003.50
Grey granite	URL-5-274.51	180	58.1	0.22	265.85
	URL-5-334.0	130	58.8	0.25	323.14
	URL-5-370.0	176	56.2	0.25	357.35
	URL-5-450.9	163	54.1	0.37	435.06
	URL-5-496.8	186	53.1	0.27	478.52
	n = 12	$\bar{x}$ = 166	$\bar{y}$ = 55.2	$\bar{z}$ = 0.25	
		S_x = 16.0	S_y = 2.4	S_z = 0.06	

Table 8 - Type three characteristics: tensile stregnth characteristics, elastic modulus grouping of all specimens tested

Rock type	Specimen	Elastic modulus zone	Tensile strength
Grey granite	URl-1-177.50	1	9.3
	URL-1-184.34		9.6
	URL-1-184.37		9.6
	URL-1-191.67		9.5
	URL-1-283.07		9.0
	URL-5-127.87		8.8
	URL-5-133.12		9.8
	URL-5-133.25		8.2
	URL-5-138.98		9.9
	n = 9		$\bar{x}$ = 9.3
			S_x = 0.5
	URL-1-292.87	2	8.6
	URL-1-293.00		8.1
	URL-1-300.00		8.2
	URL-5-274.61		8.0
	URL-5-274.64		9.0
	URL-5-277.78		7.2
	URL-5-281.73		6.2
	n = 7		$\bar{x}$ = 7.9
			S_x = 0.9

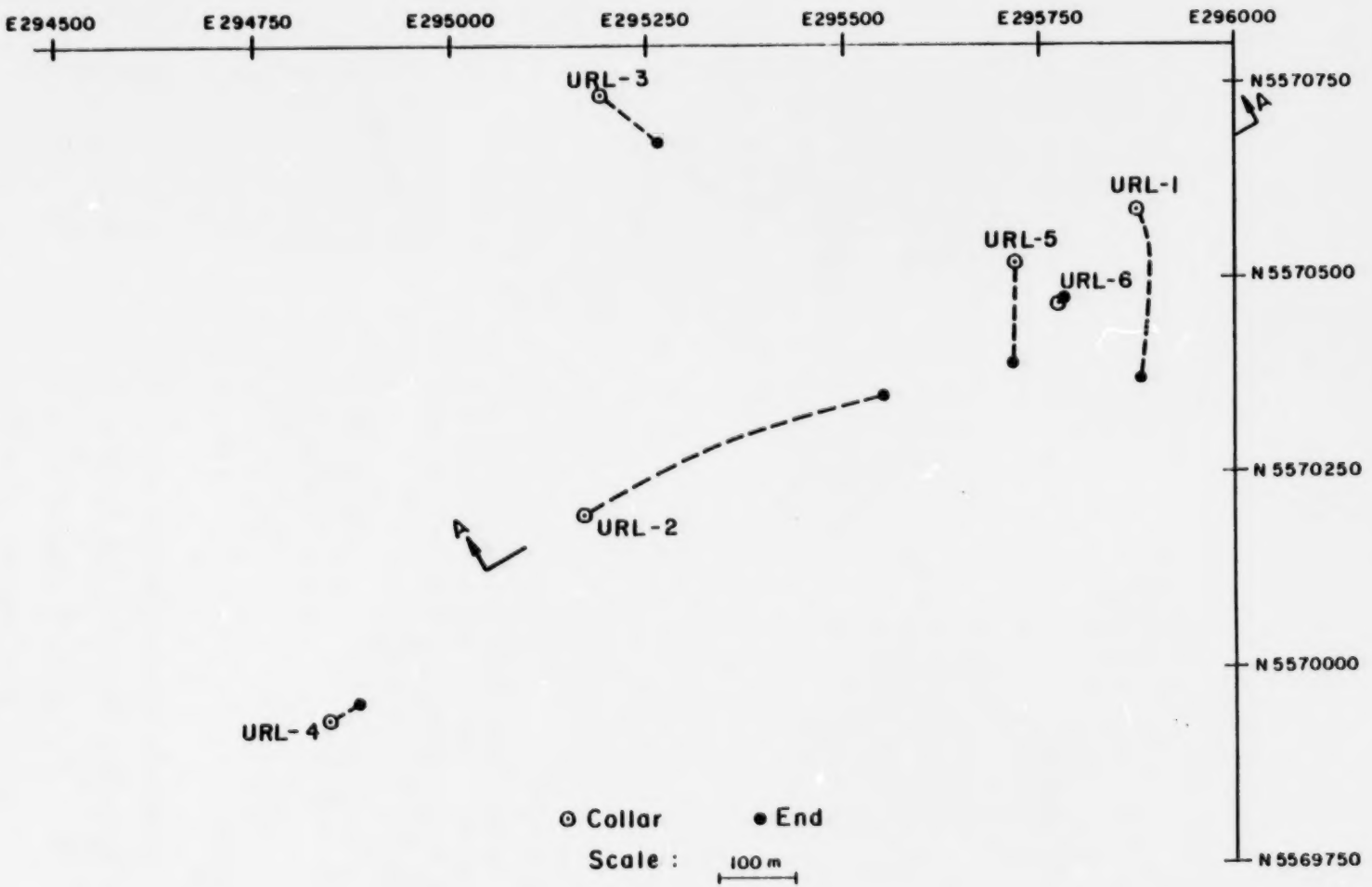

Fig. 1 - Plan, URL boreholes location (using G.S.C. directional surveys) supplied by J. Dugal

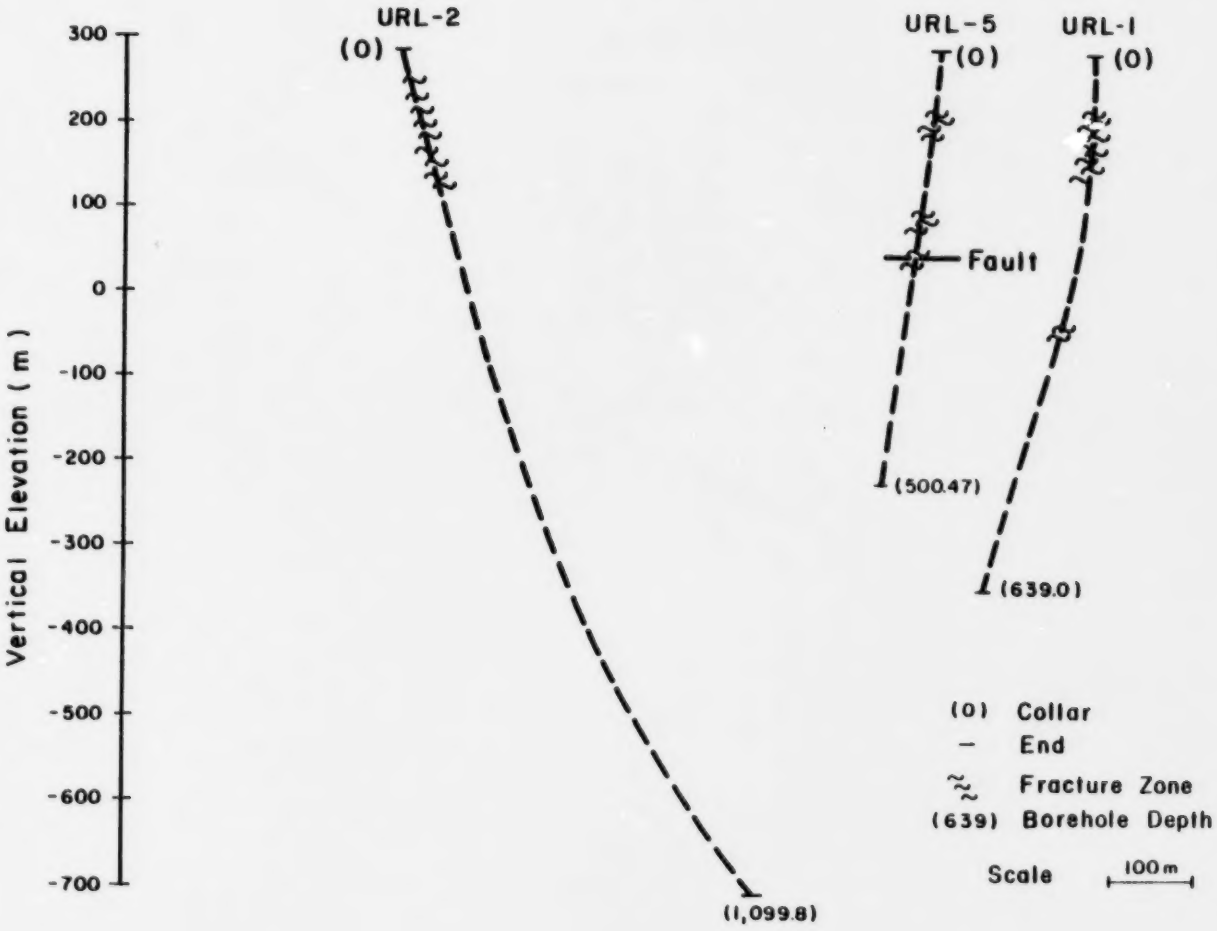

Fig. 2 - Section A-A, projection of borehole data on vertical plane oriented N60E (using G.S.C. directional surveys)

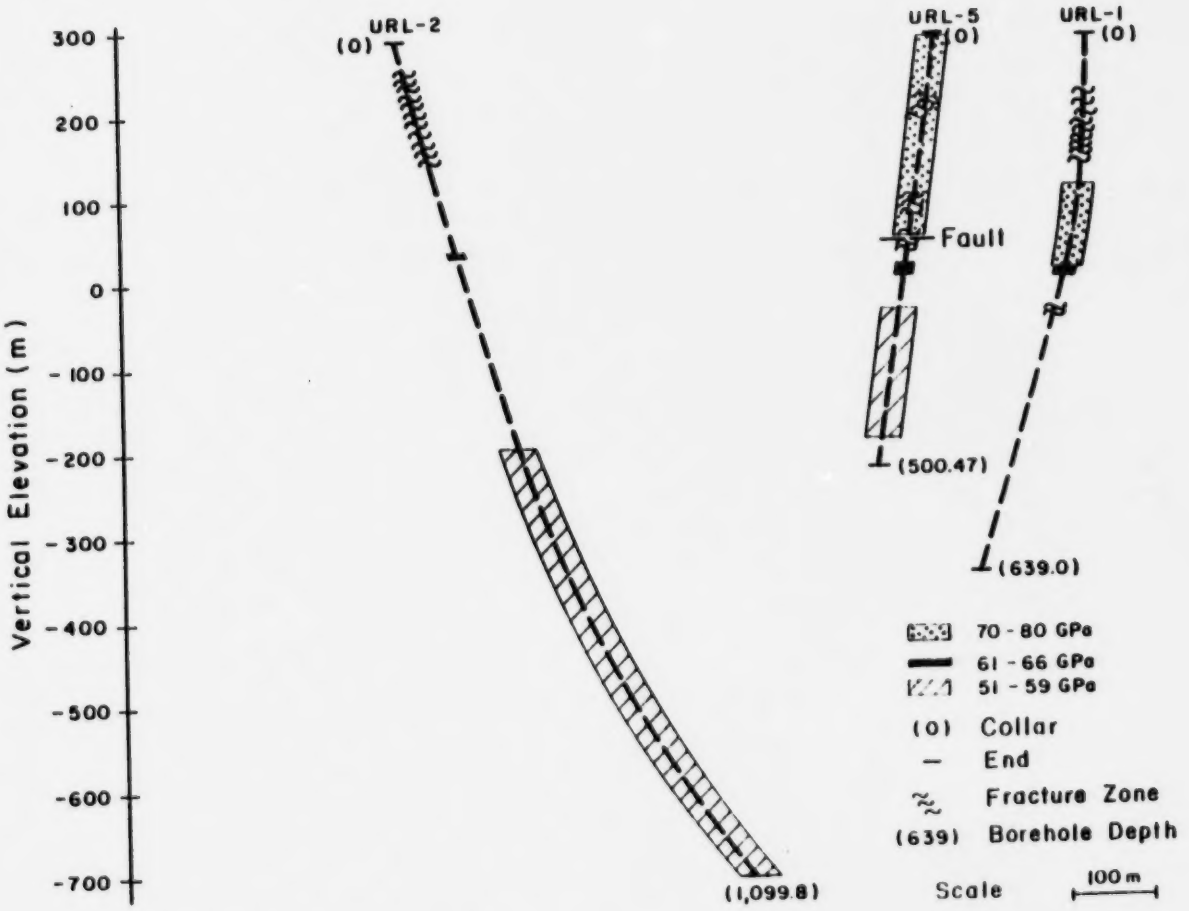

Fig. 3 - Section A-A, delineation of borehole horizons based on elastic modulus (using G.S.C. directional surveys)